InterPore2022

Efficient Permeability Prediction of Real Digital Rock Based on Darcy's Law

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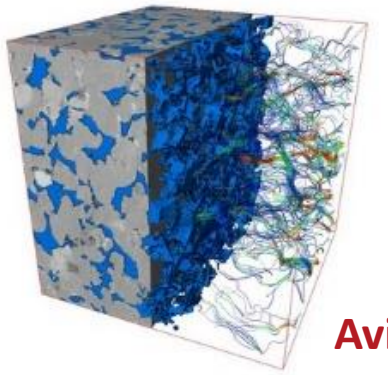
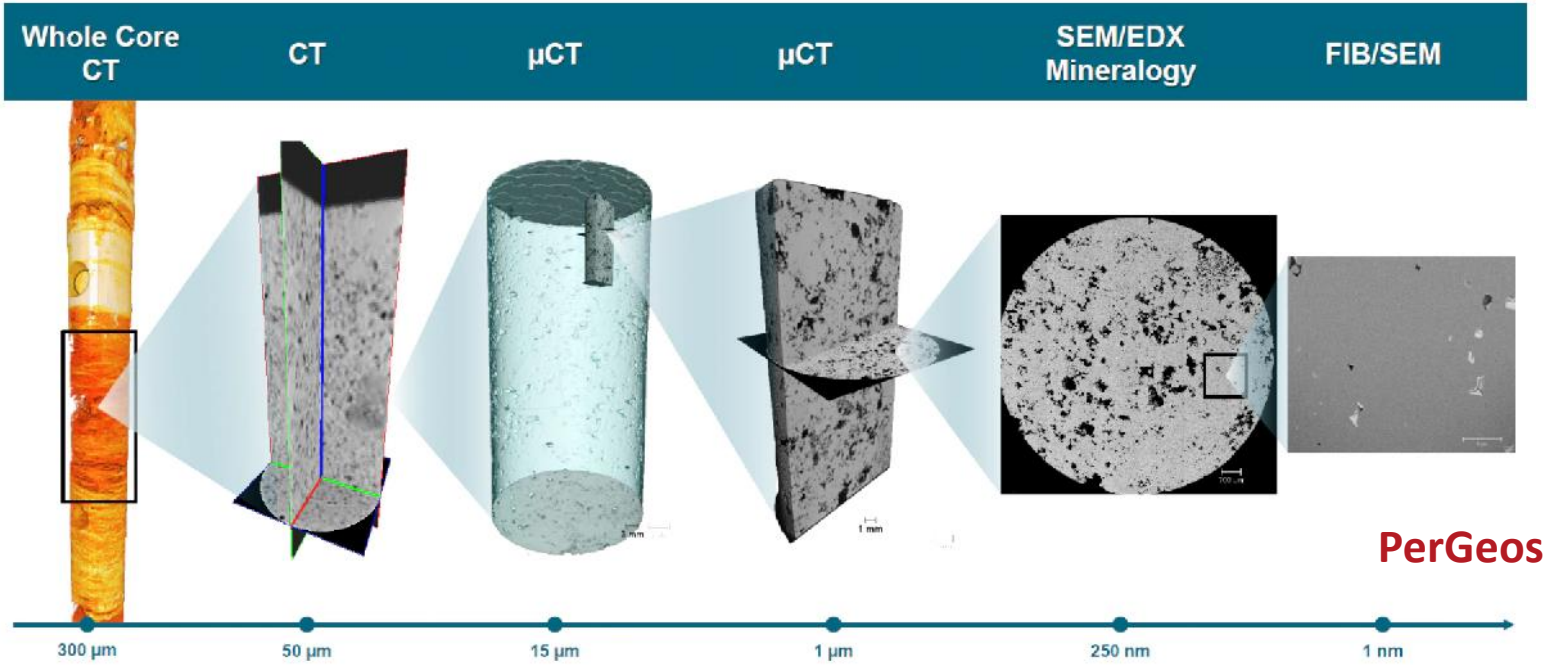
Background

- Digital rock analysis: pore-scale
- Permeability: key parameter
- Upscaling: fine to coarse



Avizo



PerGeos

Stokes Equation

- Navier-Stokes equation

$$\rho\left(\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}\cdot\nabla)\mathbf{v}\right) = -\nabla p + \mu\nabla^2\mathbf{v}$$

- Stokes equation

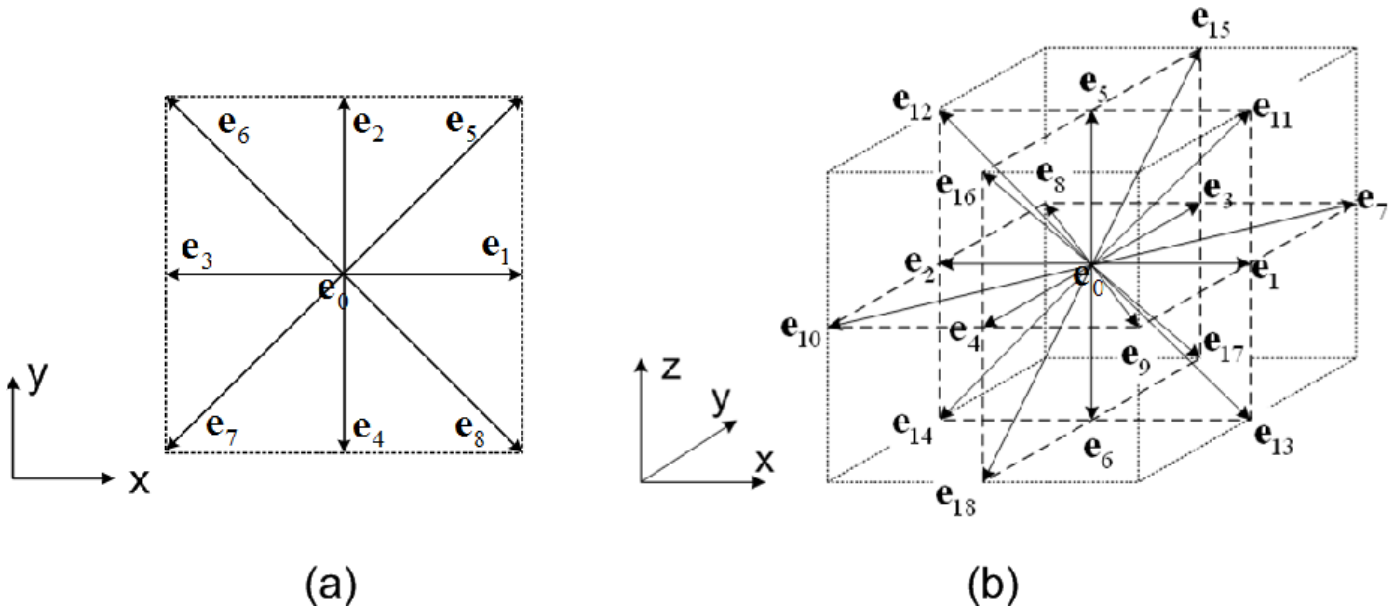
$$\mu\nabla^2\mathbf{v} = \nabla p$$

- Mass conservation equation

$$\nabla\cdot\mathbf{v} = 0$$

Lattice Boltzmann Method (LBM)

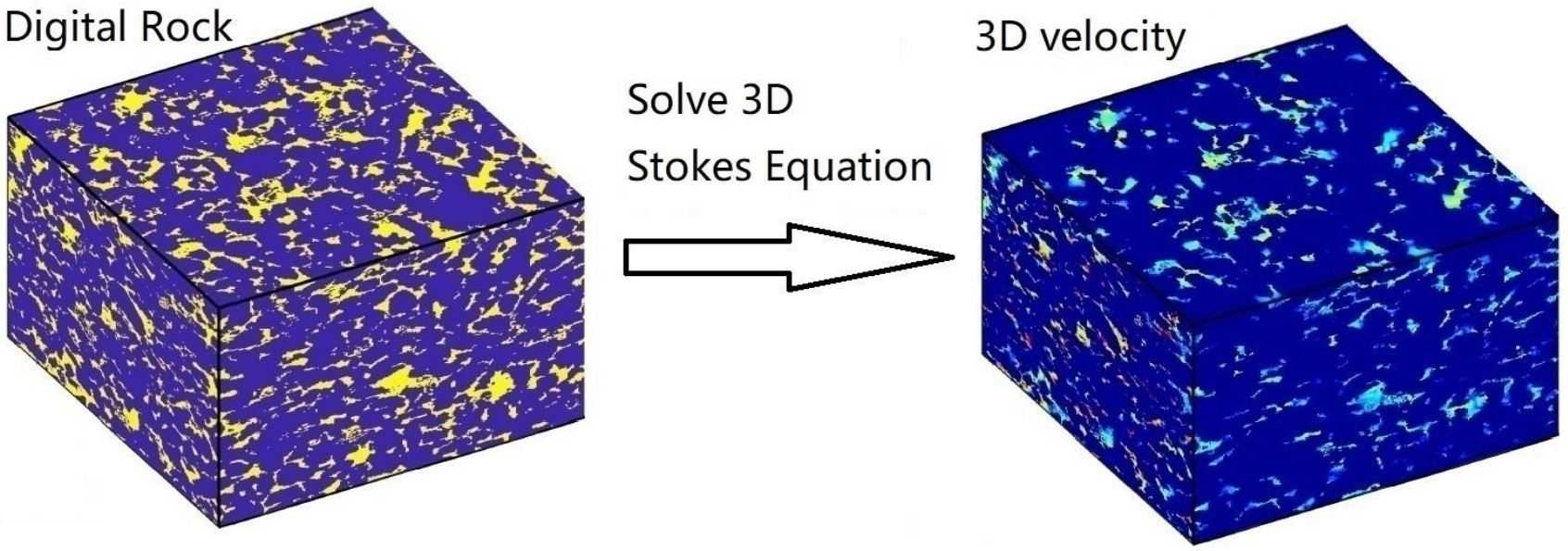
- Achieved considerable success
- Large-scale simulation: still time-consuming



Discrete velocity lattices in (a) D2Q9 and (b) D3Q19 models.
(Shin K. Kang, 2010)

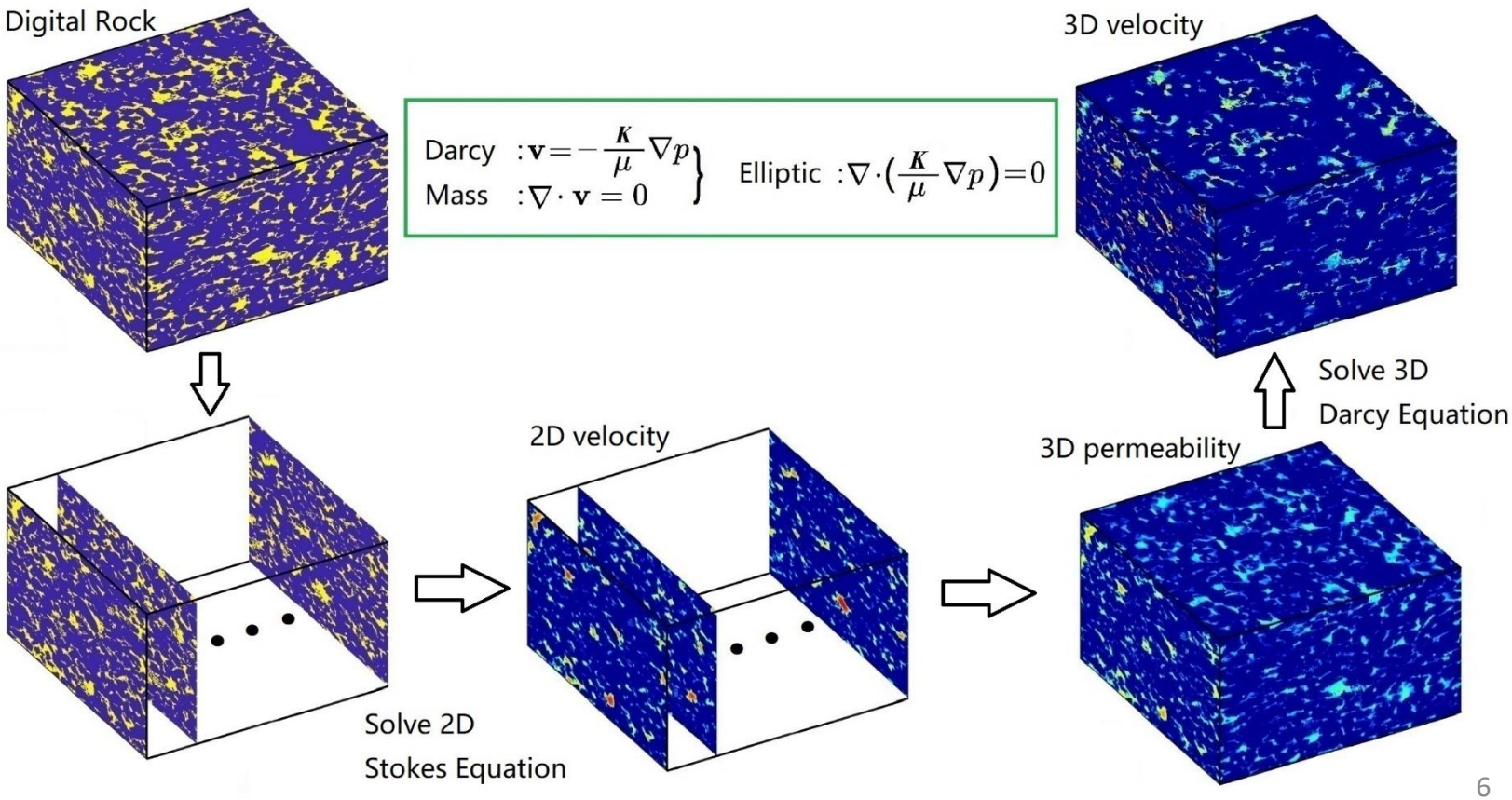
Traditional Method

- Directly solve 3D Stokes equation



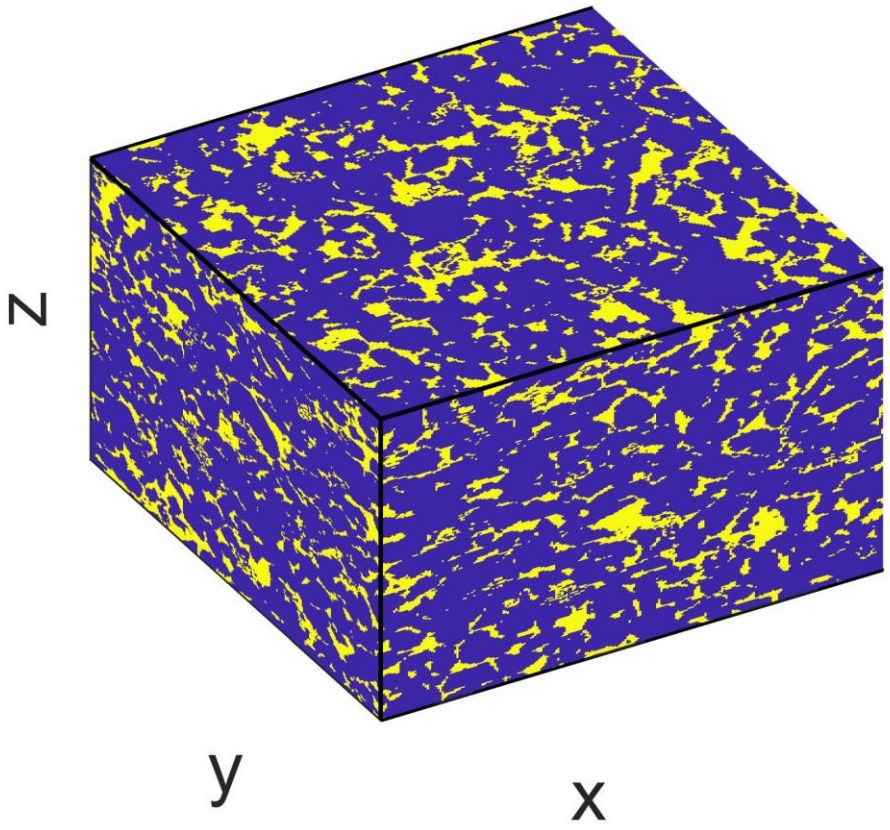
Proposed Method

- Convert Stokes equation to Darcy equation



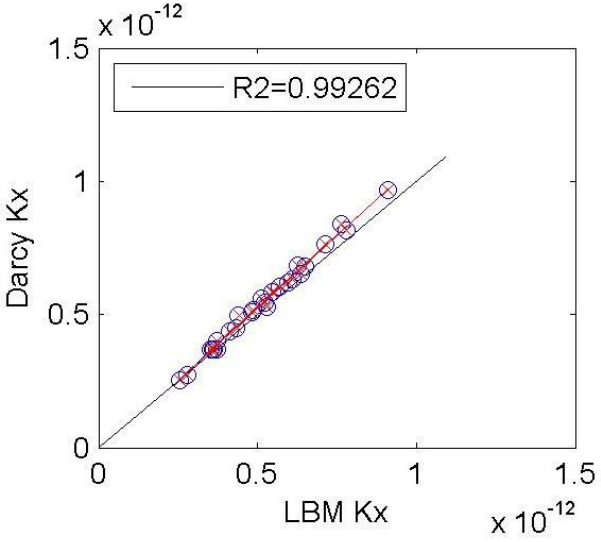
Case Studies

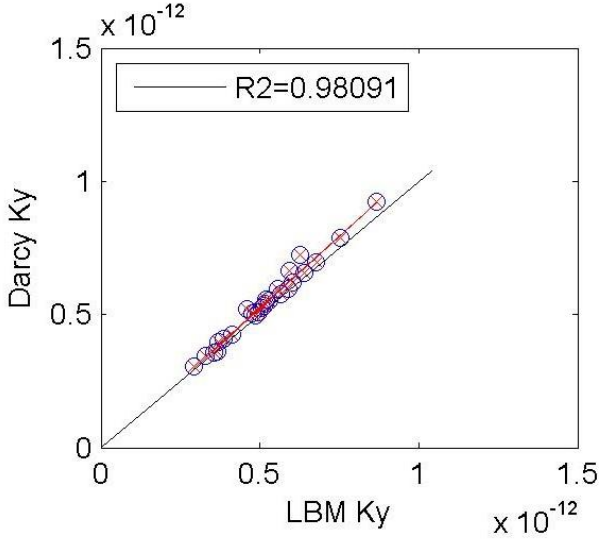
- 960*960*960 cut into 320*320*320
- 27 cubes

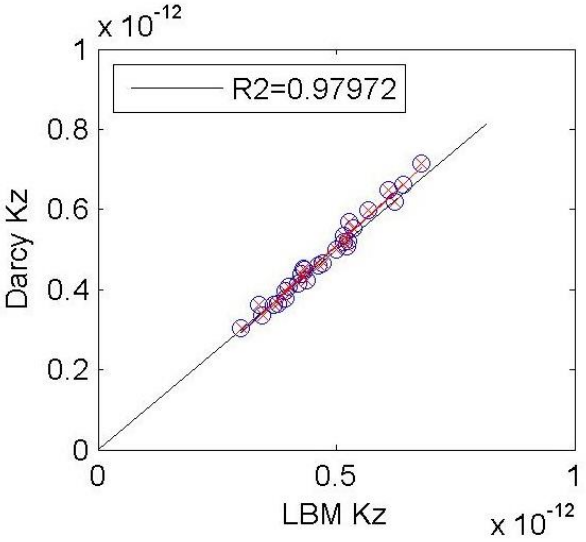


Results

- 3 directions: Kx, Ky, Kz
- $R^2 > 0.97$
- Error ~= 8%

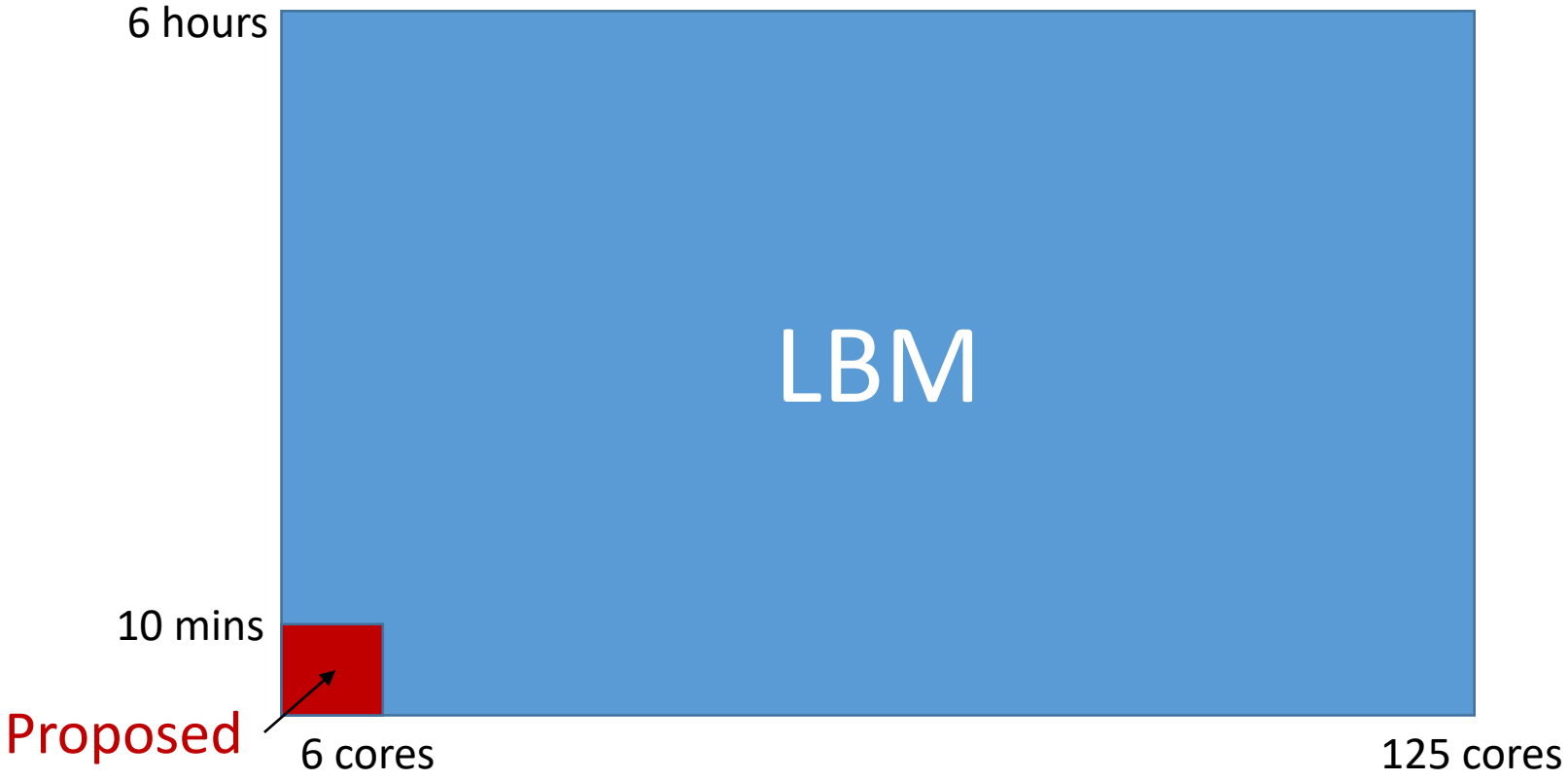




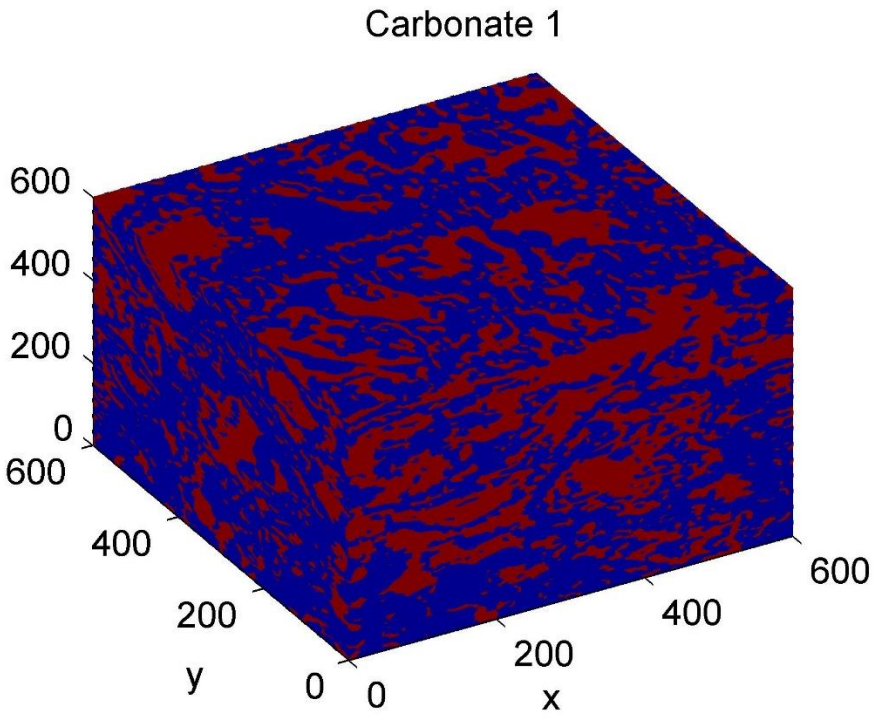


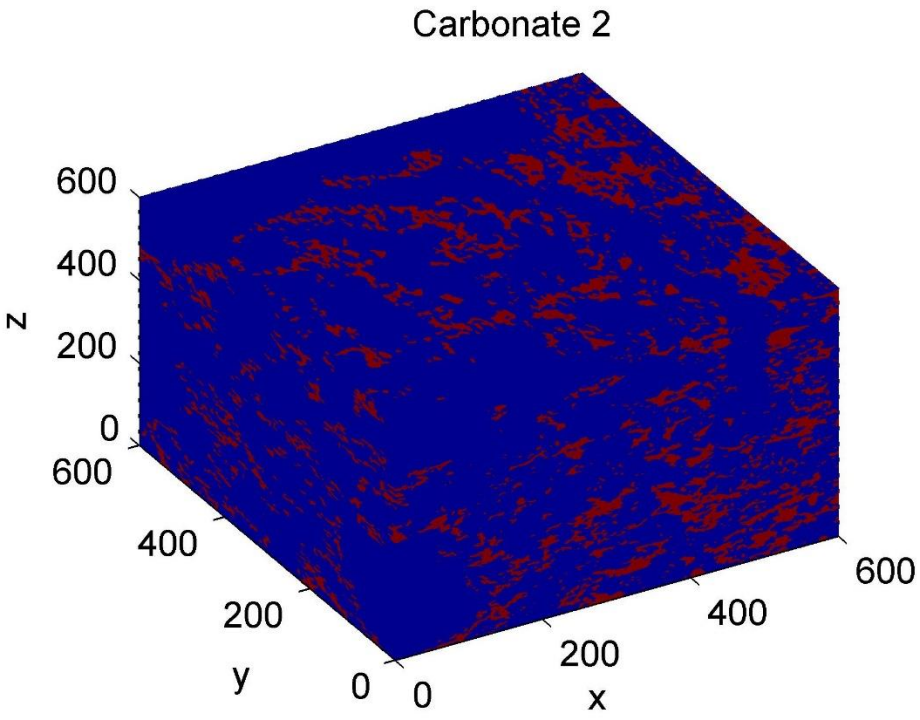
Results

- Speedup: 750 times!

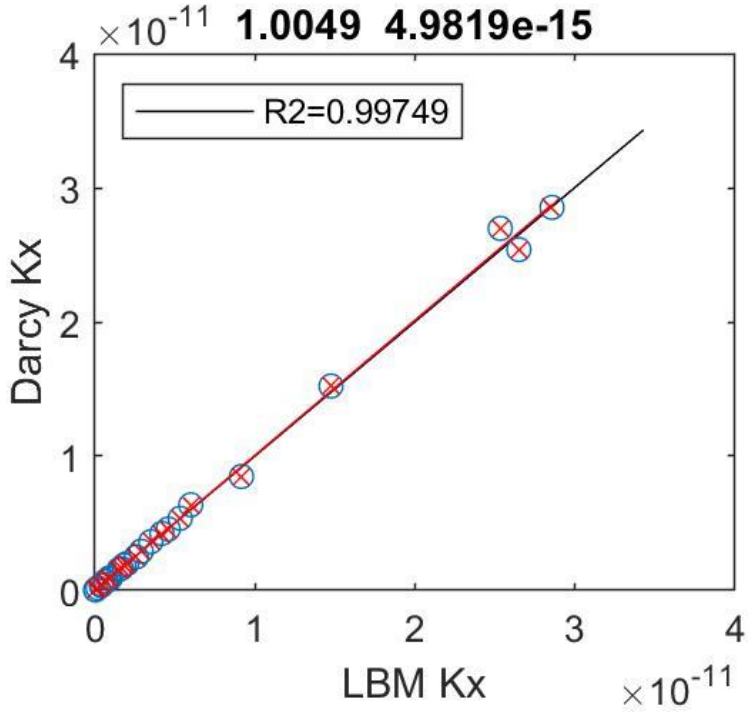


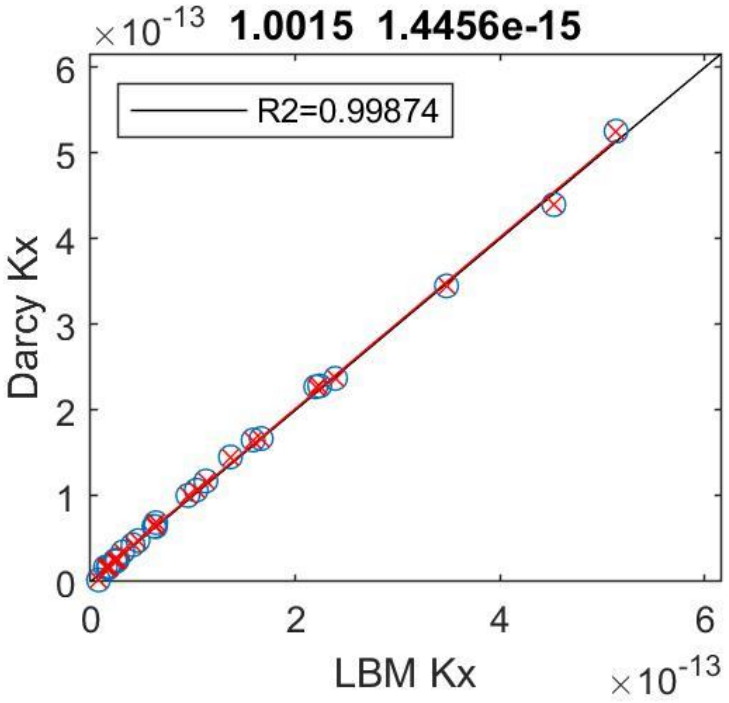
Results


Carbonate 1
600
400
200
0
600
400
200
0
y
0
200
400
600
x


Carbonate 2
z
600
400
200
0
600
400
200
0
y
0
200
400
600
x

Results


×10^-11 1.0049 4.9819e-15
R2=0.99749
Darcy Kx
LBM Kx
×10^-11
0
1
2
3
4


×10^-13 1.0015 1.4456e-15
R2=0.99874
Darcy Kx
LBM Kx
×10^-13
0
1
2
3
4
5
6

Takeaway

- An new method for Digital Rock Upscaling
- Idea: convert Stokes Equation to Darcy Equation
- Results
  - Sufficiently accurate: 8% error
  - Very efficient: 750 times faster
- Future work
  - More tests: carbonate, fracture
  - Extension: multiphase flow

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Thank You!

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